What is Claimed is:

1. A frequency offset estimation method for utilizing in a communication system in the environment of an inter-symbol-interference channel with receiving unit, a plurality of data symbols and a receiving sample sequence generated by a

5 plurality of continuously received receiving sample sections having a phase shift and an angular frequency offset, wherein each of said plurality of receiving sample sections is corresponding to one of said plurality of data symbols and contains a plurality of samples which are received continuously; the method comprising the steps of:

10 (a) selecting a first and a second selected receiving sample sections from said plurality of receiving sample sections mapping to the same state of the data symbols and each of said two selected receiving sample sections being indicated by a symbol index; each symbol index being one of a plurality of continuous symbol indices integers corresponding respectively to continuous received

15 receiving sample sections of said received sample sequence; and obtaining a symbol index difference by a difference of respective symbol indexes of said two selective receiving sample sections;

(b) complex-multiplying two selective receiving samples of the two selected receiving sample sections, respectively, wherein one of said two selective

20 receiving samples is taken complex conjugate before said complex multiplication, thereby, generating a multiplied value; and

(c) repeating said steps (a), (b) for different samples of said two selected receiving sample sections, and for different samples of another different two selected receiving sample sections, respectively, of said plurality of said

25 receiving sample sequence, thereby, generating a plurality of multiplied values; and a plurality of symbol index differences, respectively.

(d) obtaining a plurality of generic terms generated from said plurality of multiplied values;

13

(e) generating a plurality of phase angle values of said plurality of generic terms; and dividing said plurality of phase angle values by said plurality of symbol index differences, respectively thereby, generating a plurality of frequency offset estimations;

5 (f) weighting-averaging said plurality of frequency offset estimations by corresponding weighting factors to generate an average frequency offset estimation.

2. The method of claim 1, wherein said step (a) further comprising the sub-steps

10 of:

(a.1) defining a first state designated by a first segment of predetermined number n of said plurality of continuous data symbols;

(a.2) separating said first receiving sample section from said received sample sequence responsive to said first segment of predetermined number n of said

15 plurality of continuous data symbols;

(a.3) generating a symbol index corresponding to said first receiving sample section;

(a.4) storing said first receiving sample section and said symbol index as a stored receiving sample section and stored symbol index of the said first state;

20 (a.5) defining a second state designated by another segment of n continuous data symbols of said plurality of data symbols;

(a. 6) comparing said second state with said first state;

(a.7) repeating said steps (a.2) to (a.4) to form another set of receiving sample section and symbol index for said receiving sample section and storing them as

25 stored receiving sample section and stored symbol index of the said second state responsive to an inequality of said second state and said first state;

(a.8) separating said second receiving sample section from said received sample sequence responsive to said another segment of predetermined number n of said

14

plurality of continuous data symbols, responsive to an equality of said second state and said first state; and

(a.9) updating said stored receiving sample section and stored symbol index of the said first state by said second receiving sample section and symbol index of said second receiving sample section, responsive to an equality of said second state and said first state.

3. The method of claim 1, wherein said step (b) further comprising the steps of:

(a.10) determining a complex conjugate value to a selected sample of said first selected receiving sample section; and

(a.11) executing a complex multiplication to said complex conjugate value and a selected sample of said second selected receiving sample section which is at a corresponding position with respect to said selected sample of said first selected receiving sample section so as to acquire a multiplied value.

4. The method of claim 1, wherein said generic term is an accumulated value of selected multiplied values.

5. The method of claim 4, wherein said selected multiplied values are selected from any two receiving sample sections with the same symbol index difference there between.

6. The method of claim 1, wherein said generic term is said multiplied value.

7. The method of claim 1, wherein said plurality of data symbols is pre-stored in said receiving unit of said channel.

8. The method of claim 1, wherein said plurality of data symbols is detected by said receiving unit of said channel.

9. The method of claim 1, wherein in step (f), selection of said weighting factor minimizes the variance of the estimation.

10. The method of claim 1, wherein in step (f), equal weight is utilized.

11. The method of claim 4, wherein in step (f), weighting factors are selected to be proportional to a frequency of occurrences of each said index difference.

15

12. The method of claim 11, wherein in step (f), when statistics of said data symbol sequence are known and fixed, the weighting factors are calculated in advance from said statistics.

13. The method of claim 11, wherein a set of counters are used to dynamically count the number of occurrences of each of said index differences, and the counter values are utilized to generate said weighting factors.

14. The method of claim 1, wherein only one frequency offset value is obtained and said weighting factor of said only one frequency offset value is equal to one.

15. The method of claim 2, wherein said step (a. 1) further comprises a state reduction step before determining said first state of calculating a phase rotation value responsive to a selected data symbol within said segment of n data symbols of said receiving symbol sequence, and then rotating phases of other data symbols within in said segment of n data symbols with said phase rotation value of said selected data symbol.

16. The method of claim 1, wherein said step (a. 2) further comprises a step of rotating phase of said samples in said first selected receiving sample section with said phase rotation value of said selected data symbol.

17. The method of claim 1, wherein said communication system is a spread spectrum communication system.

18. A frequency offset estimation device utilized in an inter-symbol interference channel of a communication system, in a receiving unit of said channel, a plurality of data symbols being pre-stored or detected and a receiving sample sequence being received, wherein said receiving sample sequence has a phase shift and an angular frequency offset and is formed by a plurality of receiving sample sections; each of said plurality of receiving sample sections is corresponding to one of said plurality of data symbols and contains a plurality of samples which are received continuously; the device comprising:

a state selector for determining a first state from a plurality of predetermined

states responsive to a first segment of a predetermined number of continuous data symbols; the state selector outputs said selected state;

a receiving end for receiving said received sample sequence and separating a first receiving sample section from said received sample sequence responsive to said first segment of a predetermined number of continuous data symbols, said receiving end outputting said received sample sequence;

a counter for sensing the separation of said first receiving sample section from said received sample sequence and then generating a first symbol index responsive to said first receiving sample section; said counter outputting said symbol index;

a state bank having inputs of said selected state from said state selector, said received sample sequence from said receiving end; and said first symbol index from the counter; wherein said state bank stores a plurality of stored receiving sample sections and stored symbol indexes for said plurality of predetermined states; outputting the stored receiving sample section and the stored symbol index of said selected state as the selected receiving sample section and the selected symbol index; updating said stored receiving sample section and said stored symbol index of said selected state by said first receiving sample section and said first symbol index corresponding to said receiving sample sequence;

a differential calculator being installed between said state bank and said receiving end and receiving inputs of said received sample sequence and said first symbol index from said receiving end and said selected sample section and said selected symbol index from said state bank, wherein said differential calculator determines a complex conjugate of said selected sample section; and execute a complex multiplication to a sample of said first receiving sample section of said received sample sequence and a corresponding one of said selected sample section outputted from said state bank so as to acquire a multiplied value; and a difference between said symbol index of said first

symbol index and said selected symbol index from said state bank is calculated to obtain an index difference; said differential calculator outputting said multiplied value and said index difference; and

an accumulating and averaging unit having inputs of the said multiplied value and said index difference from said differential calculator; said accumulating and averaging unit having a plurality of branches each corresponding to one index difference, said multiplied value being dispatched to a corresponding branch responsive to said index difference, and calculating a phase angle of said multiplied value; said phase angle in each branch being divided by said index difference of said branch; finally, a weighted average operation being performed over different branches, thereby, a frequency offset estimation in the receiving unit being acquired.

19. The device of claim 18, wherein said state bank further comprising:

a distributor having inputs of said received sample sequence and said first symbol index from said receiving end; said distributor separating a plurality of samples in said receiving sample sequence into a sample section responsive to said selected state and outputting said sample section and said symbol index; and

a plurality of state units each receiving and storing said receiving sample section and said symbol index outputted from said distributor in response to said selected state; each state unit having a symbol memory for storing sample section and an index memory for storing said symbol index from said receiving end in response to said selected state from said state selector; and

a symbol selector for selecting said data symbol section and said symbol index corresponding to said sample section in response to said selected state from said state selector.

20. The device of claim 19, wherein said distributor is a multiplexer.

21. The device of claim 19, wherein said symbol selector is a demultiplexer.

18

22. The device of claim 18, wherein each of said branch further comprising:

an accumulator having an input of said multiplied value for accumulating said multiplied values;

a phase calculator having inputs from said accumulator for determining a phase
5   of said multiplied value; and

a scale calculator having inputs from said phase calculator for determining a scale of said multiplied value.

23. The device of claim 18, further comprises :

state reduction phase means having an input of a selected data symbol from said
10   plurality of data symbols for calculating a phase rotation value responsive to said selected data symbol, and outputting said phase rotation value of said selected data symbol;

first phase rotation means receiving said phase rotation value of said selected data symbol for rotating phases of other data symbols with said phase rotation
15   value of said selected data; and

second phase rotation means receiving said phase rotation value of said selected data symbol for rotating phases of said receiving symbol sequence with said phase rotation value of said selected data.

24. The device of claim 23, wherein a complex conjugate of said selected data
20   symbol is selected as a state-reduction phase;

25. The circuit of claim 23, wherein a predetermined mapping from said data symbol to said phase is used in selecting a state-reduction phase.

26. A method for deriving a frequency offset estimation based on a state-based differential accumulation utilized in an inter-symbol interference channels of a
25   communication system having a slow channel variation with respect to an observation time, thereby, the channel being treated as in static condition within an observation window; in a receiving unit of said channel, a plurality of data symbols being pre-stored or detected and a receiving sample sequence being

19

received, wherein the communication system has a plurality of parameters which are a scalar gain of said channel, a phase shift of a continuous-time receiving signal, an angular frequency offset, a transmitted data symbol, an equivalent composite impulse response combing effects of transmission pulse shaping filters, channel impulse responses, and receiving filters, and a period of data symbol transmission; an additive noise process being taken into consideration; the method comprising the steps of:

(b. 1) deriving a continuous-time received signal from said plurality of parameters;

(b. 2) taking samples at a predetermined rate, thereby, obtaining a discrete received sample sequence;

(b.3) defining a state to be a predetermined number of data symbols of said plurality of data symbols;

(b.4) for any two identical states in said receiving sample sequence, performing a differential operation, i.e., complex-multiplying one receiving sample with another receiving sample having the same state and defining a new variable of a multiplied value for the result; and

(b. 5) taking phase of said multiplied value so to find said frequency offset estimation.

20

589915v1